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The role of solar energy in mitigation and adaptation to climate change: perspectives for Brazil 2030

O papel da energia solar na mitigação e adaptação às mudanças climáticas: perspectivas para o Brasil 2030

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ABSTRACT
This article aims to analyze the contributions of solar energy associated with the Nexus Approach (NA): food, water and energy security, as part of the climate change (CC) adaptation and mitigation agenda, which are part of the Nationally Determined Contribution (NDC) of Brazil in the Paris Agreement. The methodological procedures adopted were: bibliographic and exploratory research and analysis of two cases of solar energy: one on the *Minha Casa*, *Minha Vida* (MCMV) program and one in Small Farms (SF) residences. The study shows the following results: Cases 1 and 2 correlate with adaptation and mitigation strategies. As for synergy with food, water and energy security, case 1 has low synergy with water, high with energy and average with food; case 2 shows high synergy with water, energy and food. The study is relevant scientifically since it analyzed cases that combine adaptation and mitigation to the vulnerabilities provoked by the climatic changes.

Keywords: Climate Change, Renewable Energy, Mitigation and Adaptation.

RESUMO
Este artigo tem como objetivo analisar as contribuições da energia solar, associada com a Abordagem Nexus: segurança alimentar, hídrica e energética, como parte da agenda de adaptação e mitigação às mudanças climáticas (MC), que fazem parte da Contribuição Nacionalmente Determinada (NDC) do Brasil. Os procedimentos metodológicos adotados foram: pesquisa bibliográfica, exploratória e análise de dois casos de energia

solar, sendo: um em residências do Programa Minha Casa Minha Vida (MCMV) e um em Pequenas Propriedades Rurais (PPR). O estudo demonstra como resultados: Os casos 1 e 2 apresentam correlação com as estratégias de adaptação e mitigação. Quanto à sinergia com segurança alimentar, hídrica e energética, o caso 1 tem baixa sinergia com água, alta com energia e média com alimento; o caso 2 apresenta alta sinergia com água, energia e alimento. O estudo é relevante cientificamente pois analisou casos que combinam adaptação e mitigação às vulnerabilidades provocadas pelas mudanças climáticas.

Palavras-chave: Mudança climática, Energia Renovável, Mitigação e Adaptação.

1 INTRODUCTION

The world has gone through major crises, each closer to the other, and they reflect complex problems that affect the lives of people on every continent. The phenomenon of climate change represents the greatest threat humanity has faced in the course of its history. The changes resulting from the increase in the greenhouse effect could raise the number of environmental catastrophes to truly frightening levels, greatly increasing the systemic risk of life threatening on Earth (Giddens, 2010; Rifkin, 2012).

In 2015, countries gathered within the scope of the United Nations (UN), including Brazil, adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDG). Until 2030, with these new Goals that universally apply to all, countries recognize that ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, social protection, and job opportunities, while tackling climate change and promoting environmental protection (UN, 2015).

As a result of an effort of 195 nations to address climate change, a new agreement was adopted at the 21st Conference of Parties (COP21) of the United Nations Framework Convention on Climate Change in response to the threat of climate change and to strengthen countries capacity to adress the impacts of climate change. The commitment is to prevent that the increase in global average temperature surpasses 2°C above pre-industrial levels, seeking to limit the temperature rise to 1.5°C above pre-industrial levels (UNFCCC, 2015; IPCC, 2018).

In Brazil, the National Congress approved and concluded the ratification process of the Paris Agreement on September 12, 2016. On September 21, the instrument was delivered to the United Nations. As a result, the Brazilian targets became official commitments through the Nationally Determined Contributions (NDC), in which the country presented its contribution to reducing greenhouse gas emissions (MMA, 2017).

Brazil's NDC is committed to reduce greenhouse gas emissions by 37% below 2005 levels by 2025 with a subsequent indicative contribution of reducing greenhouse gas emissions by 43% below 2005 levels, in 2030. To this end, the country commits itself to increase the share of sustainable bioenergy in its energy matrix to approximately 18% by 2030, restoring and reforesting 12 million hectares of forests, as well as achieving an estimated 45% share of renewable energies in the composition of the energy matrix in 2030 (MMA, 2017).

The NDC of Brazil implies an estimated 66% reduction in greenhouse gas emissions per unit of GDP (emission intensity) in 2025 and 75% in terms of emission intensity in 2030, both in relation to 2005. Brazil, therefore, will reduce greenhouse gas emissions in the context of a continuous increase in population and GDP, as well as per capita income (MMA, 2017).

In addition, the Paris Agreement requires developed countries to invest 100 billion dollars a year in measures to combat climate change and adaptation in developing countries. There is also the possibility of financing between developing countries, called "South-South cooperation", which increases the number of project sponsors (MMA, 2017).

From the beginning of the agreement, cycles of review of these greenhouse gas reduction targets will take place, every five years, with the aim of increasing countries' ambitions and emission reduction targets, avoiding any setbacks.

In this context, full of complex problems that require a balanced situation that can minimize the effects of climate change, there is a tendency to increase energy demand in 50% by 2035, at a time when there are strong pressures for investment in renewable energy sources (BRASIL, 2017).

Although the Brazilian energy matrix is considered to be one of the cleanest in the world, where renewable energy sources account for 43.8% of the total, against a global average indicator of 24.1%, it is necessary to rethink this model. When the analysis focuses on the electric power subgroup, renewable sources represent 83.3%, while the hydraulic source alone accounts for 67.9% of the domestic supply of electricity. Rethinking the model meets the precautionary principle, as the hydraulic source can be strongly impacted by the vulnerabilities caused by climate change due to changes in rainfall regimes (MME, 2017; MICHELS, 2018).

This high concentration in a source that, although being renewable, is highly dependent on regularity of the rainfall regime, implies in raising the risk of energy security and often involves socio-environmental impacts of great proportions and high implantation costs. The need to adapt to changes in the rainfall regime, as well as to the long periods of drought experienced in the last 5 years, has ignited an alert to build an agenda that combines mitigation and adaptation to climate change in relation to the imminent risk of collapse of the model of electric power generation from the country's hydraulic source.

In view of the above, this article aims to answer the following problem situation: how can solar energy contribute to the adaptation and mitigation agenda for climate change in Brazil by 2030?

One way to answer this question is to address the issue through the Nexus Approach (NA) by Rasul and Sharma (2015), which seeks to benefit from the link between food, water and energy security, taking advantage of the synergy between them, increasing efficiency of the use of resources and encouraging greater political coherence of individual, collective and state actions, combining programs to adapt and mitigate the effects of climate change.

The objective of this work is to analyze the possible contributions of solar energy associated with food security, water and energy generation, as part of the adaptation and mitigation agenda to minimize the negative impacts caused by climate change in the context of the reached commitments in the Nationally Determined Contribution (NDC) from Brazil in the Paris Agreement by 2030.

The methodological procedures adopted in this work were: bibliographic and exploratory research: a) bibliographical, researched books and articles dealing with the NA; b) exploratory, with analysis of documents of the energy planning of Brazil for 2030, especially of renewable sources (solar energy), National Energy Plan (PNE), National Adaptation Plan (PNA) and NDC of Brazil with the Paris Agreement. To the documentary analysis was added the presentation of two cases of solar energy in residences (houses and apartments) of the *Minha Casa, Minha Vida* Program (MCMV) and 1 (one) case of solar energy in small farms. The three cases sought to combine adaptation and mitigation strategies with the vulnerabilities caused by Climate Change.

The justification for this work stems from the need to evaluate the possible contributions of renewable energy sources, so that Brazil can successfully implement a joint agenda that involves adaptation and mitigation actions to the vulnerability caused by Climate Change, due to the greenhouse effect and, at the same time, to comply with what was proposed in the NDC Brazil, to meet what was settled in the Paris Agreement for the year 2030.

2 THEORETICAL FRAMEWORK

2.1 CONCEPTS OF ADAPTATION AND MITIGATION TO CLIMATE CHANGE

The concept of adaptation, although it has received different approaches since Darwin's postulates, when it comes to climate, it refers to the adjustment of socio-ecological systems to changing natural conditions. In the context of climate change research, the concept relates to vulnerability, defined as the degree to which a system is susceptible or unable to cope with the adverse effects of climate change, including climatic variability and weather extremes. (SMIT et al., 2001 apud RODRIGUES FILHO, LINDOSO, 2016).

For the Intergovernmental Panel on Climate Change (IPCC), adaptation to climate change is the process of adjusting to the current or future climate and its effects. In human systems, adaptation seeks to mitigate, avoid harm or explore beneficial opportunities. In natural systems, human intervention can facilitate adjustment to the future climate and its effects (IPCC, 2014).

In this regard, since the 1990s, several countries have incorporated the debate on the need to act on the changes in the climate and the consequent adoption of policies aimed at reducing negative impacts on socio-ecological systems. Thus, mitigation actions are designed to act on the sources of greenhouse gas (GHG), mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (IPCC, 2014).

Mitigation is defined as the human intervention to reduce emissions by sources of greenhouse gases and to strengthen removals by carbon sinks, such as forests and oceans (MMA, 2017).

Faced with the challenge of climate change, the State assumes a fundamental role in addressing the characteristics of the problem. Toledo (2016) highlights the diffuse causes throughout the economy that, even differentiated in each country, have global impacts, disconnection between responsibilities for emission sources and persistence of the gases' effects in the atmosphere.

Thus, national policies are being designed by each country to reduce emissions and present their results in the effort involving most countries as part of the UN Framework Convention on Climate Change (UNFCCC). The main policies are grouped into three main categories: a) emission pricing mechanisms; b) Policies to reduce barriers to emissions reductions and c) Additional R&D (Research and Development) promotion policies for private investments (TOLEDO, 2016).

The same author considers that from experiences in mitigation and adaptation over the last decades, many cases, mainly in the European Union, have presented the need for integration and articulation of national and sectoral policies. Coordination between policies involves embedding the objectives of one policy at all stages of the political cycle of the other.

In this sense, the NA has emerged as a response to the challenges of today's world, which aims to benefit from the synergy between investments that seek to increase safety between water, energy and food production (BELLFIELD, 2015).

This approach, which deals with food safety, water security and energy security, is called nexus, a term that was given highlight in 2011 when the German government organized the International Conference "The Water Energy and Food Security Nexus - solutions for the Green Economy "(RASUL & SHARMA, 2015).

2.2 THE LEGAL FRAMEWORKS OF CLIMATE AND THE NEXUS APPROACH (NA): FOOD, WATER AND ENERGY SECURITY

Rasul and Sharma (2016) described an approach that identifies the importance of linkages, or interconnections between water, energy and food security, and how these are treated in a sectoral way in development policies and in relation to climate change.

In Brazil, the legal framework for tackling climate change is the National Policy on Climate Change (PNMC) (Law 12.187/2009) and Decree 7.390/2010, which regulates the PNMC and determines the elaboration of the Sectorial Plan for Mitigation and Adaptation to the Climate Change. For the elaboration of these Sectorial Plans, in 2012 a Working Group was created for the development of the National Adaptation Plan (NAP) (BRASIL, 2016).

The NAP is divided into sectors such as Agriculture, Water Resources, Food and Nutrition Security, Biodiversity, Cities, Disaster Risk Management, Industry and Mining, Infrastructure, Vulnerable Populations and People, Health, and Coastal Areas. The energy sector is contemplated in infrastructure (BRASIL, 2016).

In 2013, the Adaptation WG started its activities and in the following year it held a Public Call for the NAP and mobilization of thematic networks. In 2015 the Public Consultation of the NAP was carried out and in 2016 the Plan was launched. The Plan that guides the adaptation of the energy sector is the Ten-Year Energy Plan.

This segmentation in sectors is one of the criticisms in the NA regarding adaptation policies. Rasul & Sharma (2016) argue for the importance of interlinkages in approaches to water, energy and food production and their implications for sustainable development and adaptation. Potential synergies and complementarities between sectors should be used as a guide for the formulation of effective adaptation options. The issues highlight the need for a shift in sectoral policy approaches, which can result in competing and/or counterproductive actions, for an integrated approach with policy coherence across sectors that use knowledge of interconnections to maximize earning, optimize trade-offs and avoid negative impacts.

Therefore, the Ten-Year Energy Plan 2026 (PDE) provides an estimate that up to 48% of the Internal Energy Supply will be from renewable sources. However, data released in 2018 show that, although wind has registered a percentage increase, the expansion of renewable, in absolute numbers, for the generation of electric energy is quite timid. To this end, the PDE forecasts growth in the use of biofuels and increased energy efficiency measures (BRASIL, 2015).

On the other hand, the same PDE forecasts a production of 5 million barrels of oil/day in 2026, double the amount registered in 2016. By the end of the decade, the pre-salt will account for almost 75% of the national production of Petroleum (BRASIL, 2015; EPE, 2015).

Therefore, it is perceived that the interconnection between the sectors is a fragile point of adaptation to the climatic changes in Brazil.

The NA demonstrates that failure to disregard the water, energy and food nexus in assessments and policy-making led to contradictory strategies and inefficient resource use.

In general, there are two distinct perspectives on how to approach adaptation in the context of developing countries. The first focuses on reducing the impacts of climate change and the second on reducing vulnerability and creating resilience by addressing not only climate change but also other factors of vulnerability, poverty, gender, social equity, as well as other structural factors which make long-term sustainable development difficult (RASUL & SHARMA, 2016).

Development-oriented the NA emerged on the premise that people are vulnerable not only to climate change but also to a series of other stresses, depending on access to resources and other socio-environmental circumstances shaped by economic policies and processes. Technological measures designed to help people adapt to specific changes in the climate may not address the issues that communities consider most urgent, such as access to water, food, energy and livelihood security.

It is increasingly recognized that successful adaptation will require interventions that address the full spectrum of challenges, including the underlying causes of vulnerability, risk management and responsiveness in the context of other risk and development theories (RASUL & SHARMA, 2016).

Rasul and Sharma (2016) quote the work of Schipper (2007), who emphasizes that adaptation will not be effective unless integrated into development policies and processes. According to the authors, so far, there is no framework or set of principles for sustainable adaptation that has been agreed upon by all stakeholders, and some key principles can be discerned:

a) adaptation involves measures that reduce poverty and vulnerability and increase long-term resilience;

b) adaptation comprises actions that strengthen the adaptive capacities of the poor, including the management of the natural resources on which their livelihood depends; risk management; and use of resources efficiently and sustainably to meet the needs of present and future generations;

c) adaptation in one sector or community does not affect the resilience of others;

d) responses and adaptation mechanisms do not jeopardize long-term sustainability.

Thus, sectoral adaptation strategies can increase vulnerability or impair resilience, reducing capacity or promoting increased risk elsewhere or in a sector, resulting in poor adaptation.

Balochistan, the arid region of Pakistan, is now cultivating apples and other fruits using groundwater irrigation, which requires huge amounts of energy. Meanwhile, the country faces energy shortages (RASUL & SHARMA, 2016).

Thus, for the authors, as the adaptive capacity of those affected by climate change ultimately depends on their access to poverty reduction opportunities, adaptation plans can only be effective if they are incorporated into the development agenda. This is necessary to ensure that adaptation policies do not run counter to development - the so-called "maladaptation".

Therefore, adaptation plans must be integrated, taking into account climate policies and sectoral policies, focusing on three central axes of socioecological systems: water, energy and food security.

2.3 ENERGY SECURITY AND THE ROLE OF RENEWABLE SOURCES IN BRAZIL

The demand for more energy is a continuous thing in a world always moving around growth and economic development. In 2010, the U.S. Energy Information Administration (EIA) projects that global energy demand will grow 44% by 2030, with the price of a barrel of oil expected to reach US$130 (DOGGETT, 2010).

With regard to energy demand in Brazil, for the same period, the demand is increasing, and the Internal Energy Supply (OIE) is expected to be of the order of 99.6%, which will be detailed below, when presenting the evolution of the Brazilian energy matrix from 2005 to 2030 (BRASIL, 2015; EPE, 2015).

The growth of the OIE projected for 2030 is necessary precisely to meet the expectation of demand for the same period. Hence the importance of planning and investing in renewable energy sources, such as solar, wind and bioenergy, which is not demonstrated in the national energy matrix 2030 of the MME (Ministry of Mines and Energy), and EPE (Enterprise in Energy Research), which in fact maintains the emphasis on hydraulic sources and investments in the wind power source (EPE, 2016).

The Brazilian energy planning foresees that energy security is guaranteed until 2030, with the conclusion of ongoing projects and investments still in the planning stage. The National Energy Plan 2030 (PNE 2030), prepared by MME/EPE (2015), recognizes that in analyzing the "behavior of energy consumption vis-à-vis the evolution of GDP suggests the existence of an inertial component that inhibits the growth of energy demand in the case of high GDP growth rates" (MME / EPE, 2015).

Therefore, it is possible to conclude that there is a small margin between supply and demand of energy in the present, and this narrow margin remains in the short, medium and long term projections.

The Brazilian energy matrix is one of the most diversified in the world, presenting in 2017 a slight decrease in the share of fossil sources compared to the previous year, which was 36.8% to 36.2%, respectively. The set of renewable sources shows the inverse, that is, an increase in supply from 43.6% to 43.8% in the same period. This is close to the commitment made by Brazil, which aims to raise the target of the participation of renewable energy sources to 45% of the national energy matrix in the year 2030. This apparent comfort begins to become alarming when it is verified that the OIE in the country needs to grow by approximately 100% by 2030, against an average global increase of around 40% (MME, 2017).

As for the electric energy segment, Brazil remains in the world's top supplier of renewable energy sources, with an 83.3% share in 2017 against 82.7% in 2016 (BRAZIL, 2017).

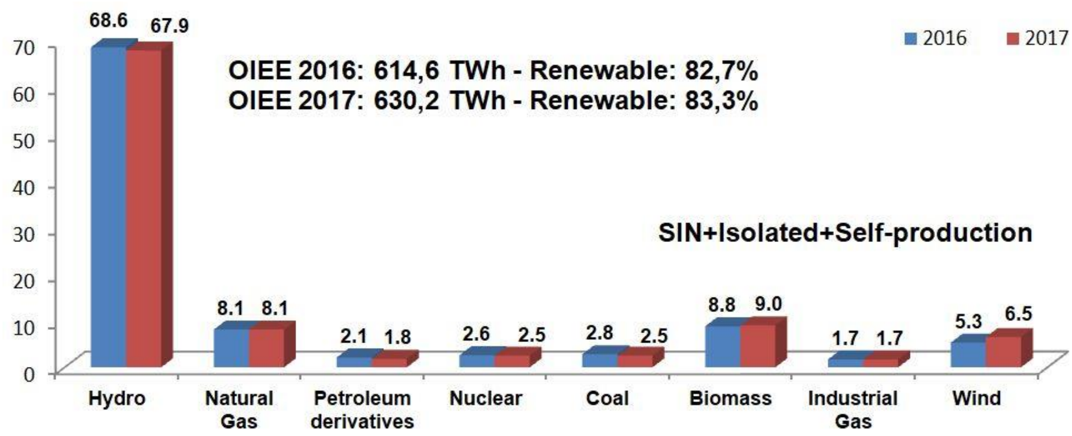

Figure 1 - Domestic electricity supply (OIEE), by source and by percentage
Source: BRAZIL (2017).

Even in times of long periods of drought, which require to increase the supply of electricity by means of the activation of thermoelectric plants, the OIE, derived from Petroleum and Coal Derivatives, has shown a decline in participation, with the former falling from 2.1% in 2016 to 1.5% in 2017, and the second fell from 2.8% to 2.5% in the same period, as indicated in the previous figure (BRASIL, 2017).

Projections on the national energy matrix, prepared by the Brazilian government, indicate that the OIE, both by 2020 and by 2030, will be driven by the increase in the demand of people, since the OIE per capita (toe/inhabitant) shows a significant increase, rising from 1.19 in 2020 to 2.33 in 2030, representing a rise of 95.8% in the period under analysis, according to figure 2 (BRASL, 2017; EPE, 2015).

In figure 2, the Energy Intensity Indicator (EII), which in 2005 was 0.28 (toe/ thousand US$), will reach 0.29 (toe/thousand US$) by 2020 and is expected to fall in 2030 to 0.26 (toe/thousand US$), which confirms that the Brazilian economy is on the decarbonization line, according to figure 2 (BRASIL, 2017; EPE, 2015).

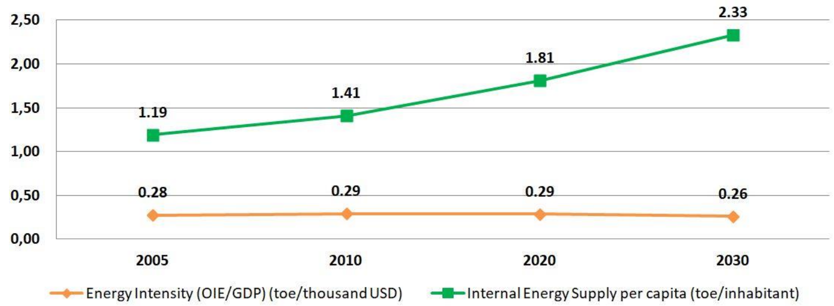

Figure 2 - Indicator of EI and OIE per capita (OIE toe10^6/GDP at US$$10^6$ in 2005).
Source: Made by the authors with data from BRAZIL (2017) and EPE (2015).

The prospect of increasing the EII, as shown in Figure 2, for 2020, as well as the fall forecast for 2030, are in line with the forecasts for the Brazilian Final Energy Consumption Indicator (ICFE) and the Final Consumption Indicator (ICF) , by sector of the economy/GDP (toe/thousand US$), according to Figure 3.

The ICF shows that the performance of the Industrial, Agricultural and Services sectors, regarding the strategy of the national economy. consumption of energy resources, is in line with the decarbonization strategy of the national economy.

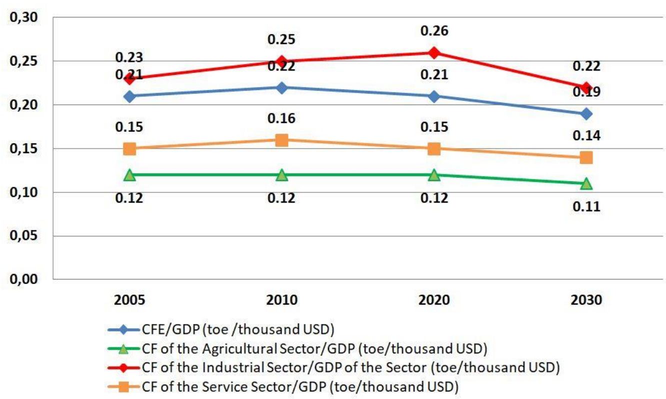

Figure 3 - Indicator of CFE and CF in the sectors of the economy GDP (toe/thousand U$S).
Source: Made by the authors with data from BRAZIL (2017) and EPE (2015).

On the other hand, it is observed that the Indicator of Total Electricity Consumption/Population (ICETp) in MWh/inhabitant, presents a growth rate in the order of 110.66%, from 1.97 in 2005 to 4.15 in 2030, according to figure 4.

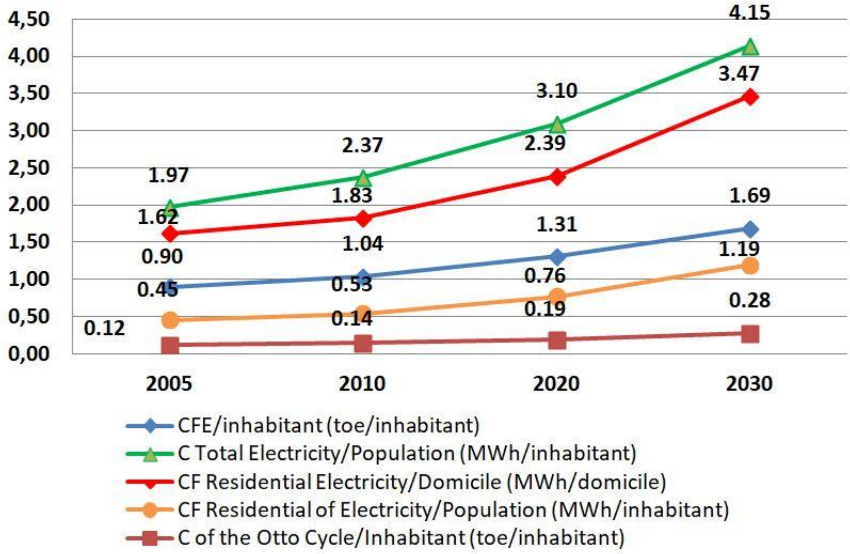

Figure 4 - Indicator of CFE (toe/inhabitant), CET (MWh/inhabitant) and CF MWh/domicile/inhabitant).
Source: Made by the authors with data from BRAZIL (2017) and EPE (2015).

Unlike what happens with the ICFE/GDP, and the ICF/sectors of the economy, which show a reduction for the year 2030, the Final Energy/Population Consumption Indicator (ICFEp) in (toe/inhabitant), ICETp in MWh/inhabitant, the Household Final Consumption of Electricity/Domicile (ICFREd) in MWh/Domicile, the Household Final Consumption of Electricity/Population (ICFREp) in MWh/inhabitant, the Otto/Inhabitant Cycle Consumption (CCOh) in toe/inhabitant, show they are all increasing since 2005 and, they also show a tendency of a sharp increase for the period of 2020 to 2030, according figure 4.

To cope with the increasing demand, the viable and environmentally sound alternative is to expand the supply of energy from renewable sources.

Along these lines, ANEEL estimates that by 2024, there should be at least 1.2 million units totaling 4.5 GW, capable of generating its own energy solar. By 2030 it should reach 10% with 25 GW, still far behind countries like China and Germany, with installed capacity of 75 GW and 40 GW, respectively (CANTO, 2017).

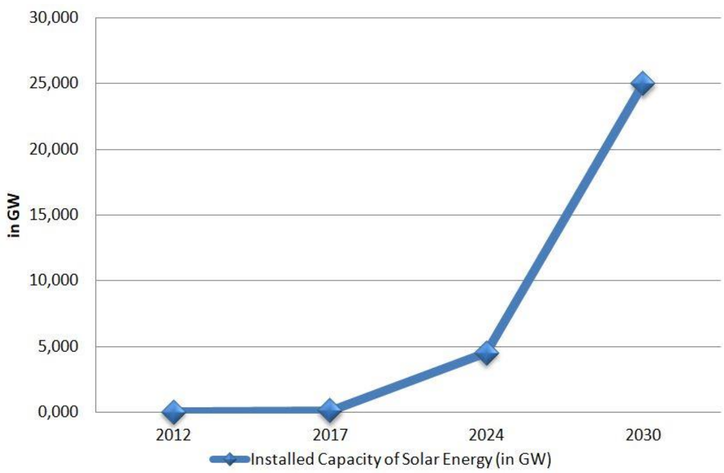

Figure 5 - Installed capacity of solar energy for 2012 and 2017, forecast for 2024 and 2030
Source: Made by the author with data from EPE (2016).

The Brazilian energy potential of a renewable source of solar energy generation is 28,500 GW and is distributed throughout the country (EPE, 2016).

The expansion of investments in solar energy at a national scale, with projects in urban and rural areas, requires the development of a new model of energy planning, which should be focused at the local level (COLLAÇO; BERMANN, 2017).

The Distributed Energy Resources (DER), which are energy generation and storage technologies, have a great disruptive potential in the sector, with capacity for growth and gaining scale at high speed, they require adaptations in both planning and market models and the regulatory framework (EPE, 2018).

3 CASES THAT COMBINE THE ADAPTATION AND MITIGATION AGENDA: SOLAR ENERGY

3.1 CASE 1: RESIDENTIAL - MCMV PROGRAM AND MRV CONSTRUCTION COMPANY

The Federal Government's *Minha Casa Minha Vida* (MCMV) housing program moved a large part of the construction market between 2008 and 2017, when 6.3 million housing units were launched, as reported by the Brazilian Association of Real Estate Developers (ABRAINC), according to ABAINC/FIPE (2017). These data, when annualized, reach an average of 630 thousand units/year. MRV Construction Company, in Belo Horizonte (MG), which is currently the largest in the country, forecasts a demand for 11.9 million housing units, for the period from 2017 to 2025, which is around 1,437.5 thousand units/year (ABRAINC / FIPE, 2017, OLIVIEIRA, 2017, SEGALA, 2017).

MRV has included, in a strategic plan for the next 5 years, an investment in the amount of R$ 800 million, to produce 40 thousand new units with a solar energy kit. During this period, 200 thousand units will be equipped with a distributed generation system which, if extended until 2030, could reach 60 thousand units/year from 2023 (2023 to 2030), making a total of 680 thousand in the two cycles (ABRAINC / FIPE, 2017, OLIVIEIRA, 2017, SEGALA, 2017).

Table 1 summarizes the demand of the Brazilian real estate market, as well as demonstrates the growth potential of solar energy in residential projects (ABRAINC/FIPE, 2017; OLIVIEIRA, 2017).

Table 1 - Demand for housing units in Brazil - from 2018 to 2030

Period (Forecast)	Quantity (Thousand units)	Average/year (Thousand units)	Income Class (Thousand units)	
			Average/High = 10%	Low = 90%
2018 to 2025	11,900.0	1,487.5	1,190	10,790
2026 to 2030	8,000.0	1,600.0	800	7,200
	19,900.0		1,990	17,920

Source: Made by the authors with data from (2019): ABRAINC/FIPE (2017), Oliveira (2017) and Segala (2017)

Based on initiatives such as that of the MRV Construction Company and the MCMV program, it is possible to believe that the solar power generation program should take off in the coming years. The projects aimed at the low-income public account for 90% of the market, with about 900 thousand units/year from 2017 to 2030 and 600 thousand units/year from 2026 to 2030 (ABRAINC/FIPE, 2017; OLIVEIRA, 2017; SEGALA, 2017).

The case under analysis has a potential to mitigate climate change, through the reduction of CO_2 emissions in the Distributed Generation of Electric Energy (DGEE) from the solar source, which will be of the order of 11,676.06891 Mt CO_2 or 42.851,17288 Mt CO_2 by 2030.

The adaptation strategy is also present in this context of production of residential solar power, as this initiative will increase the family income of this population in the order of R$ 125,963 million in 2018 and R$ 1,685,160 million in 2030. Smaller expenditures have a direct impact on increasing net household income and greater availability of food in the household.

3.2 CASE 2: SMALL FARMS: FAMILY FARMING

The potential for growth of solar installed capacity in rural properties is very high, provided that long-term credit lines with low interest rates are created, consistent with those already practiced in family agriculture.

The land structure of Brazil, where 85% of the 3,871,671 properties, that is, 3,275,123 have an area of less than 100 hectares, are part of the group of producers of the family agriculture segment, who demand solar energy as a way of adapting to climate changes (INCRA, 2017).

The growth of solar energy in distributed generation must take place on a large scale in the segment of small producers linked to family agriculture, as follows: 1) Adaptation strategy: a) allows the supply of water for family use and consumption of animals, due to the reduction of water from streams and dams (which have dried in the period from June to November); b) contributes to adequacy to the forest code, with closure of APPs (Permanent Preservation Areas); c) provides regularity in the production of family agriculture. The reduction in annual energy expenditures will reach R$ 223,527 million in 2030, with a direct positive impact on household income. 2) Mitigation strategy: a) reduction of the use of fossil fuels to pump water, which is getting further and further, over the last few years; b) reduction of investment in concessionaire’s electric power networks, if there is a need to serve more than one point in the property. The mitigation of accumulated emissions by 2030 will be on the order of 957.06818 Mt CO_2e.

4 RESULTS AND DISCUSSION

This section presents the results and discussion of the exploratory, bibliographical and documentary research relevant to solar energy, especially distributed generation, both in MCMV residences (houses and apartments for low income families) and in small farms, as explored in Cases 1 and 2, previously presented.

Cases 1 and 2 analyzed followed the NA, focusing on food, water and energy security, based on the combination of a market that demands technology, equipment to generate solar energy, with qualified and willing to serve suppliers, which made possible the analysis proposed in this work, including strategies for mitigation and adaptation to the vulnerability of climate change.

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Table 2 - NA analysis: food, water and energy security

CASES		WATER	ENERGY	FOOD	STRATEGY	
					Adaptation	Mitigation
1	Solar Energy - MCMV	Low	High	Average	Yes	Yes
	Solar Energy - MRV	Low	High	Average	Yes	Yes
2	Solar Energy - PPR	High	High	High	Yes	Yes
LINES UP WITH THE SDG						
						

Source: Made by the authors (2019)

The MCMV and MRV solar energy cases received a "low" relevance in the item "Water", because they only marginally contribute to the supply in the case of building (pumping) and collaborate effectively with water heating; the item "Energy" was rated as "high" because it is "solar" renewable energy; the item "Food" received a "medium" relevance assessment because it was indirectly achieved by the increase in the availability of the family budget due to the reduction of the electricity bill - which should reinforce the purchase of foods of better nutritional quality, according to table 2.

Adaptation and mitigation strategies in the MCMV and MRV cases received a "yes" response, since they are present in the projects, through the source of solar renewable energy generation, which contributes to adaptation in the face of the energy shortage of hydroelectric source and for mitigation, by reducing the possibility of using electricity from non-renewable (fossil) source from the thermoelectric, according to table 2.

The case of solar energy in small farms (PPR) received a "high" evaluation of the three items: Water, Energy and Food, and "yes" to the adaptation and mitigation strategies, because both are present in the projects. Adaptation received "yes" for combining water supply, protection of springs by the closing of APPs (adaptation to the Forest Code), use of renewable energy "solar photovoltaic", water pumping that helps in the regularity of food production (family farming: milk and dairy products, meat and products of irrigated vegetables). The "yes" to mitigation is due to the substitution of the fossil energy use (diesel oil) in the water pumping, according to table 2.

In both cases, it is possible to observe that to obtain the results of solar energy generation in the place where it is consumed, it is necessary to go beyond the DERs in order to guarantee availability of energy with quality. In the case of Brazil, it implies moving from a centralized to a decentralized model, which requires a new planning model, focusing on the local sphere (COLLAÇO et al., 2016).

Finally, it should be noted that the cases are in line with SDG 7, 11 and 13. SDG 7, since it is Affordable and Clean Energy, SDG 11, for providing Sustainable Cities and Communities and SDG 13, as it is framed as Climate Action.

5 FINAL CONSIDERATIONS

The challenges of adaptation and mitigation to climate change in Brazil consist mainly of integrating multiple policy objectives and enhancing stakeholder collaboration in sustainable adaptation, development planning and decision-making.

As observed, renewable energy sources can make a major contribution to supplying local energy demand. The DERs, represented in this study by solar energy applied to Cases 1 and 2, prove to be effective in their implementation to support adaptation and mitigation strategies to the effects of climate change.

Thus, national adaptation and mitigation plans will be strengthened from a systematic approach, and the nexus approach has proved to be effective in associating solar energy with food, water and energy security. It also has a good capacity to reduce GHG emissions, contributing to local, national and global targets for combating climate change.

However, the success of the role of renewable energies in the objectives related to adaptation and mitigation depends on the integration of policies and investments in a management model that associates food, water and energy. Otherwise, the cases studied here would be examples of "maladaptation" or failure to face the risks of climate change.

Finally, the study is scientifically relevant because it sought to analyze cases that combine adaptation and mitigation strategies to vulnerabilities caused by climate change, using resources efficiently and effectively, and also by being aligned with SDG 7, 11 and 13.

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